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PATENT  
Docket No. 58027-011900**AMENDMENTS TO THE CLAIMS**

**Claim 1 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency, the method comprising:

forming an aperture by selectively etching an active-region-aperture layer between a first and a second reflecting-cladding surface, said first and the second cladding surfaces and said aperture layer are formed on an InP substrate;

said aperture reducing loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency of said VCSEL; and

wherein the etching of the active-region-aperture layer is at a rate substantially faster higher than a rate of etching for at least one of the first and second reflecting-cladding surface.

**Claim 2 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 1, wherein the etching is performed by a mixture comprised of a predetermined ratio of citric acid to hydrogen peroxide.

**Claim 3 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 2, wherein the predetermined ratio of citric acid to hydrogen peroxide is about 3:1.

**Claim 4 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency, the method comprising:

lattice matching a first reflecting surface with a first substrate layer;

lattice matching a second reflecting surface with a second substrate layer;

wherein the first substrate layer and the second substrate layers are formed on an InP material;

etching an active-region-aperture layer on the InP material between the first and the second reflecting-surface-substrate layer to form an aperture, said aperture having a predetermined size; and

said aperture reducing loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency of said VCSEL.

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**Claim 5 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the first reflecting surface is a first Distributed Bragg Reflector (DBR).

**Claim 6 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the second reflecting surface is a second Distributed Bragg Reflector (DBR).

**Claim 7 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the first substrate layer and the second substrate layer are of InP.

**Claim 8 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the etching is performed by a mixture comprised of a predetermined ratio of citric acid to hydrogen peroxide.

**Claim 9 (original):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 8, wherein the predetermined ratio of citric acid to hydrogen peroxide is about 3:1.

**Claim 10 (currently amended):** A vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency, the VCSEL comprising:

~~a first reflecting surface;~~

~~a second reflecting surface;~~

a first and a second cladding layer, said first and the second cladding layers are formed on an InP substrate;

an active region-aperture layer substantially lattice matched to the first and the second cladding layer, the aperture layer formed on the InP substrate;

an aperture formed by selectively etching the active region-aperture layer to a predetermined size in comparison to a size of at least one of the first and second-reflecting surfaces cladding layers; and

said aperture reducing a loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency of said VCSEL.

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**Claim 11 (currently amended):** The VCSEL according to claim 10, wherein the VCSEL further comprises ~~at least one cladding layer~~ a first and a second reflecting surface substantially lattice matched to the first and the second cladding layer respectively.

**Claim 12 (currently amended):** The VCSEL according to claim ~~10~~ 11, wherein the first reflecting surface is a first Distributed Bragg Reflector (DBR) and the second reflecting surface is a second Distributed Bragg Reflector (DBR).

**Claim 13 (original):** The VCSEL according to claim 12, wherein the first DBR and second DBR are made of alternating layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$  approximately lattice matched to InP.

**Claim 14 (original):** The VCSEL according to claim 13, wherein b is greater than about 0.5, a1 is greater than about 0.9, and a2 is less than about 0.3.

**Claim 15 (currently amended):** The VCSEL according to claim 12, wherein the first DBR and the second DBR are ~~preferably~~ substantially undoped.

**Claim 16 (cancelled)**

**Claim 17 (original):** The VCSEL according to claim 10, wherein the aperture is formed by etching with a predetermined ratio of citric acid to hydrogen peroxide.

**Claim 18 (currently amended):** The VCSEL according to claim ~~10~~ 17, wherein said ratio of citric acid to hydrogen peroxide is about 3:1.

**Claim 19 (original):** The VCSEL according to claim 13, wherein the first DBR and the second DBR have between eighteen and thirty-five layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$ .

**Claim 20 (currently amended):** The VCSEL according to claim 17, wherein the ~~first reflecting surface~~ aperture layer is etched to a predetermined diameter by the citric acid and hydrogen peroxide.

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**Claim 21 (currently amended):** The VCSEL according to claim 20, wherein the ~~active-region aperture layer~~ is etched at a rate substantially faster than a rate of etch ~~applied to-of~~ at least one of the first and second ~~reflecting surfaces-cladding layers~~.

**Claim 22 (currently amended):** A vertical-cavity surface-emitting laser (VCSEL) for decreasing threshold current, the VCSEL comprising:

- a first reflecting surface;

- a second reflecting surface;

- an ~~active-region-aperture layer~~ with a first surface and a second surface, said aperture layer formed on an InP substrate;

- a first cladding layer between the first reflecting surface and the first surface of the ~~active region-aperture layer~~;

- a second cladding layer between the second reflecting surface and the second surface of the ~~aperture layer active-region~~;

- wherein said first and the second cladding layers are formed on the InP substrate;

- an aperture formed by selectively etching the ~~active-region-aperture layer~~ to a predetermined size in comparison to a size of at least one of the first and second ~~reflecting surfaces-cladding layers~~; and

- said aperture reducing a loss due to scattering in a cavity of a VCSEL, thereby decreasing threshold current in said VCSEL.

**Claim 23 (currently amended):** The VCSEL according to claim 22, wherein the first surface of the ~~aperture layer active-region~~ has a tunnel junction.

**Claim 24 (original):** The VCSEL according to claim 22, wherein the first cladding layer and the second cladding layer are made of InP.

**Claim 25 (original):** The VCSEL according to claim 22, wherein the first reflecting surface is a first Distributed Bragg Reflector (DBR) and the second reflecting surface is a second Distributed Bragg Reflector (DBR).

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**Claim 26 (original):** The VCSEL according to claim 25, wherein the first DBR and second DBR are made of alternating layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$  approximately lattice matched to InP.

**Claim 27 (original):** The VCSEL according to claim 26, wherein b is greater than about 0.5, a1 is greater than about 0.9, and a2 is less than about 0.3.

**Claim 28 (currently amended):** The VCSEL according to claim 25, wherein the first DBR and the second DBR are ~~doped~~undoped ~~uniformly with n-type material~~.

**Claim 29 (cancelled)**

**Claim 30 (original):** The VCSEL according to claim 22, wherein the aperture is formed by etching through a predetermined ratio of citric acid to hydrogen peroxide.

**Claim 31 (currently amended):** The VCSEL according to claim ~~22~~ 30, wherein said ratio of citric acid to hydrogen peroxide is about 3:1.

**Claim 32 (original):** The VCSEL according to claim 26, wherein the first DBR and the second DBR have between eighteen and thirty-five layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$ .

**Claim 33 (currently amended):** The VCSEL according to claim 30, wherein the aperture layer ~~first reflecting surface~~ is etched to a predetermined diameter by the citric acid and hydrogen peroxide.

**Claim 34 (currently amended):** The VCSEL according to claim 33, wherein at least one of the first and the second cladding layer ~~the first reflecting surface~~ is etched at a rate slower than an etch rate of the ~~active region~~ aperture layer.

**Claim 35 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency and decreasing threshold current, the method comprising:

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forming an aperture of a predetermined size by selectively etching an ~~active region~~ aperture layer between a first and a second ~~reflecting cladding~~ surface, ~~said aperture having a predetermined size and formed having an opening wherein the etching of the aperture layer is at a rate substantially higher than a rate of etching of the at least first and the second cladding surface;~~

wherein said first and the second cladding surfaces and the aperture layer are formed on an InP substrate; and

said aperture reducing loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency and decreasing threshold current of said VCSEL.

**Claim 36 (currently amended):** The method for aperturing a VCSEL according to claim 35, wherein the VCSEL further comprises ~~at least one cladding layer~~ a first and a second reflecting surface.

**Claim 37 (currently amended):** The method for aperturing a VCSEL according to claim ~~35~~ 36, wherein the first reflecting surface is a first Distributed Bragg Reflector (DBR) and the second reflecting surface is a second Distributed Bragg Reflector (DBR).

**Claim 38 (original):** The method for aperturing a VCSEL according to claim 37, wherein the first DBR and second DBR are made of alternating layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$  approximately lattice matched to InP.

**Claim 39 (original):** The method for aperturing a VCSEL according to claim 38, wherein b is greater than about 0.5, a1 is greater than about 0.9, and a2 is less than about 0.3.

**Claim 40 (currently amended):** The method for aperturing a VCSEL according to claim 35, wherein the first DBR and the second DBR are ~~doped undoped uniformly with n-type material~~.

**Claim 41 (cancelled)**

**Claim 42 (original):** The method for aperturing a VCSEL according to claim 35, wherein the aperture is formed by etching through a predetermined ratio of citric acid to hydrogen peroxide.

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**Claim 43 (currently amended):** The method for aperturing a VCSEL according to claim ~~35~~ 42, wherein said ratio of citric acid to hydrogen peroxide is about 3:1.

**Claim 44 (original):** The method for aperturing a VCSEL according to claim 38, wherein the first DBR and the second DBR have between eighteen and thirty-five layers of  $\text{Al}_{a1}\text{Ga}_{1-a1}\text{As}_b\text{Sb}_{1-b}$  and  $\text{Al}_{a2}\text{Ga}_{1-a2}\text{As}_b\text{Sb}_{1-b}$ .

**Claim 45 (currently amended):** The method for aperturing a VCSEL according to claim 42, wherein the ~~first reflecting surface aperture layer~~ aperture layer is etched to a predetermined diameter by the citric acid and hydrogen peroxide.

**Claim 46 (currently amended):** The method for aperturing a VCSEL according to claim 45, wherein ~~the first reflecting surface at least one of the first and the second cladding surface is~~ etched at a rate slower than an etch rate of the active region aperture layer.

**Claim 47 (cancelled)**

**Claim 48 (cancelled)**

**Claim 49 (currently amended):** The method for aperturing a VCSEL according to claim 40, wherein the ~~threshold current is decreased by~~ decrease in threshold current is more than about 20%.

**Claim 50 (currently amended):** The method for aperturing a VCSEL according to claim 40, wherein the ~~quantum efficiency is increased by~~ increase in quantum efficiency is more than about 10%.

**Claim 51 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency and decreasing threshold current, the method comprising:

coating a wall of at least one ~~reflecting-cladding~~ reflecting-cladding surface in a VCSEL with a dielectric to prevent substantial etching of the at least one cladding surface, the at least one cladding surface formed on an InP substrate;



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forming an aperture by selectively etching an ~~active-region-aperture layer~~ of a VCSEL with an etchant, the aperture formed on the InP substrate; and

said aperture reducing loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency and decreasing threshold current of said VCSEL.

**Claim 52 (original):** The method for aperturing a VCSEL according to claim 51, wherein the etchant is composed of citric acid and hydrogen peroxide in a predetermined ratio.

**Claim 53 (original):** The method for aperturing a VCSEL according to claim 51, wherein the etchant is either  $\text{H}_3\text{PO}_4$ , or  $\text{H}_2\text{O}_2$ , or  $\text{H}_2\text{O}$ , or any combination thereof.

**Claim 54 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency, the method comprising:

selectively etching an aperture between a first and a second cladding surface;

wherein said first and the second cladding surfaces are formed on an InP substrate;

said aperture designed to reduce loss due to scattering in a cavity of a VCSEL, thereby increasing external quantum efficiency of said VCSEL; and

wherein the aperture is etched at a rate substantially faster than a rate at which at least one of the first and second surfaces is etched.

**Claim 55 (currently amended):** A method for aperturing a vertical-cavity surface-emitting laser (VCSEL) for increasing external quantum efficiency, the method comprising:

selectively etching an aperture layer between a first and a second surface, the aperture layer being formed on an InP substrate and including at least one material with a gradually changing composition between the first and the second surface;

said first and the second surface formed on the InP substrate; wherein:

at least one of the first and second surfaces has a taper;

at least one of the first and second surfaces is formed from a first material which is etched at a rate substantially ~~faster~~ lower than the rate at which a second material forming the aperture is etched; and

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wherein a selectivity of the etching between the first material and the second material is substantially ~~greater~~lesser than unity.

**Claim 56 (currently amended):** The method according to claim 55, wherein the first material is a compound having ~~InGaAlAs~~ InAlAs.

**Claim 57 (currently amended):** The method according to claim 55, wherein the second material is a compound having ~~InAlAs~~ InGaAlAs.

**Claim 58 (currently amended):** The method according to claim 55, further including a first and a second cladding layer lattice matched to the first and second surfaces respectively ~~wherein the first and the second surface is made of InP~~.

**Claim 59 (currently amended):** The method according to claim ~~55~~ 58, wherein the first and the second cladding layer material is is formed of InP ~~and the second material contains As and is lattice matched to InP~~.

**Claim 60 (currently amended):** The method according to claim 59, wherein the ~~first and second materials are~~ aperture layer is selectively etched using an etchant containing citric acid and hydrogen peroxide.

**Claim 61 (currently amended):** A semiconductor laser comprised of:

photon reflecting mirrors;

cladding layers formed on an InP substrate;

~~an active region~~ aperture layer sandwiched between the mirrors cladding layers, the aperture layer formed on the InP substrate; and

a first etched aperture lattice matched to the InP and having a lateral surface area less than that of at least one of the ~~mirrors~~ cladding layers.

**Claim 62 (original):** The laser of claim 61 wherein the material of the aperture includes As.

**Claim 63 (original):** The laser of claim 62 wherein the material of the aperture includes a group V element.

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**Claim 64 (original):** The laser of claim 62 wherein the material of the aperture includes an element of the group including: Al, Ga, and In.

**Claim 65 (currently amended):** The laser of claim 61 further comprising a second etched aperture lattice matched to InP, having a lateral surface area less than that of at least one of the ~~mirrors~~ cladding layers, and separated from the first aperture by a layer of InP.

**Claim 66 (original):** The laser of claim 65 wherein the first aperture confines the current and the second aperture confines the optical mode.

**Claim 67 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 2, wherein the etch has a selectivity of about 100:1.

**Claim 68 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 1, wherein the aperture layer comprises of InAlGaAs.

**Claim 69 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, further comprising etching at least one of the first and the second substrate layers with a reactive ion etch.

**Claim 70 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the aperture layer comprises of InAlGaAs.

**Claim 71 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 8, wherein the etch has a selectivity of about 100:1.

**Claim 72 (new):** The VCSEL according to claim 17, wherein the etch has a selectivity of about 100:1.

**Claim 73 (new):** The VCSEL according to claim 30, wherein the etch has a selectivity of about 100:1.

**Claim 74 (new):** The method for aperturing a VCSEL according to claim 43, wherein the etch has a selectivity of about 100:1.

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**Claim 75 (new):** The method for aperturing a VCSEL according to claim 35, further comprising etching at least one of the first and the second cladding surface with a reactive ion etch.

**Claim 76 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 55, wherein the at least one material includes Al.

**Claim 77 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 55, wherein the at least one material includes Ga.

**Claim 78 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 1, wherein the first and the second cladding surfaces are made of InP.

**Claim 80 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 1, wherein the aperture layer is an active region.

**Claim 82 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the aperture layer is an active region.

**Claim 83 (new):** The vertical-cavity surface-emitting laser (VCSEL) according to claim 10, wherein the aperture layer is an active region.

**Claim 84 (new):** The vertical-cavity surface-emitting laser (VCSEL) according to claim 10, wherein the aperture layer is comprised of InAlGaAs.

**Claim 85 (new):** The vertical-cavity surface-emitting laser (VCSEL) according to claim 10, wherein the first and the second cladding surfaces are made of InP.

**Claim 86 (new):** The vertical-cavity surface-emitting laser (VCSEL) according to claim 22, wherein the aperture layer is comprised of InAlGaAs.

**Claim 87 (new):** The vertical-cavity surface-emitting laser (VCSEL) according to claim 22, wherein the aperture layer is an active region.

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**Claim 88 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 35, wherein the first and the second cladding layers are made of InP.

**Claim 89 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 35, wherein the aperture layer is an active region.

**Claim 90 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 35, wherein the aperture layer is comprised of InAlGaAs.

**Claim 91 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 51, wherein the at least one cladding surface is made of InP.

**Claim 92 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 51, wherein the aperture layer is comprised of InAlGaAs.

**Claim 93 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 51, wherein the aperture layer is an active region.

**Claim 94 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 55, wherein the aperture layer is comprised of InAlGaAs.

**Claim 95 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 55, wherein the aperture layer is an active region.

**Claim 96 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 61, wherein the aperture layer is comprised of InAlGaAs.

**Claim 97 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 61, wherein the aperture layer is an active region.

**Claim 98 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 61, wherein the cladding surfaces are made of InP.

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**Claim 99 (new):** The method for aperturing a VCSEL according to claim 61, wherein the aperture is formed by selectively etching the aperture layer by an etchant composed of citric acid and hydrogen peroxide in a predetermined ratio.

**Claim 100 (new):** The method for aperturing a vertical-cavity surface-emitting laser (VCSEL) according to claim 4, wherein the first and the second cladding surfaces are made of InP.